Ultra-low power nonlinear optics in photonic crystal mircroresonators

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The enhancement to the electromagnetic energy density provided by the large photon lifetimes and small mode volumes of photonic crystal (PC) microresonators reduces the input power required for the observation of nonlinear optical switching in these structures to micro- [1], and nano-watt levels [2]. For example, nominally weak semiconductor nonlinear processes, such as two photon absorption, free carrier absorption and dispersion, and Kerr self-phase modulation, play important roles in PC microresonators at sub-milliWatt power levels. Similarly, nonlinear processes in resonant cold atoms, whose third-order susceptibility can be 10^{10} times larger than that of typical semiconductors, are observable at single photon power levels when a single cold atom is located in a PC microresonator.

Here we report on the nonlinear response of a silicon PC microresonator. Taking advantage of an efficient fiber taper coupled PC waveguide input channel, optical bistability is observed for a dropped microresonator power of 100 uW, corresponding to 3 fJ of stored energy [1]. From these measurements a free carrier lifetime of only 0.5 ns in the highly porous PC is estimated. We also discuss the use of PCs in cold-atom cavity QED experiments, and address practical issues associated with integrating our fiber taper coupled devices with planar atom-chip waveguide systems in ultra-high vacuum environments.

[1] P.E. Barclay et al., Opt. Express (to be published).
[2] B. Lev et al., Nanotechnology, Vol 15, S556-S561 (2004).